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USER'S MANUAL FOR UCIN-CABLE: UNDERWATER CABLES.(U)
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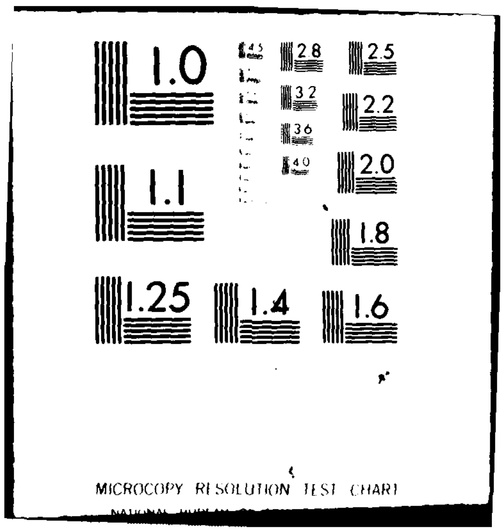
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MICROCOPY RESOLUTION TEST CHART

(12) LEVEL II

USER'S MANUAL FOR

UCIN - CABLE:

UNDERWATER CABLES

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A B S T R A C T

This report presents a user's manual for a computer program, UCIN-CABLE: Underwater Cables. The program is designed to study the dynamics of underwater cables. The cable is modeled as a series of rigid cylinders connected end-to-end by ball and socket joints. There may be one or many branches, and no closed loops are formed. The effects of normal fluid drag, tangential fluid drag, added mass, and buoyancy are included.

This manual provides detailed instructions for building a set of input data and interpreting the output of the program.

C O N T E N T S

I. INTRODUCTION

This user's manual is intended to accompany the computer program UCIN-CABLE: Underwater Cables. Subsequently, the computer program is intended to provide numerical data on the dynamics of underwater cables. The program models a flexible cable by a series of rigid cylinders connected end-to-end by ball and socket joints [1,2]*. The size, shape, and mass of each of the segments is arbitrary. (See Figure 1.) The program also allows for spherical anchors and/or towed spheres. (These bodies may only be at the end of the branches.) The fluid effects on the cable (normal fluid drag, tangential fluid drag, added mass, and buoyancy [2]) and on the appended spheres (normal fluid drag, added mass, and buoyancy) may all be included individually as desired. Finally, the program is expected to be effective in studying the nonlinear, three-dimensional, dynamical behavior of long, heavy, towing and hoisting cables.

The dynamic analysis of the cable model is a specialization of a recently developed analysis for general "chain" systems [3-6]. (A general chain system is a set of rigid bodies arbitrarily assembled and connected provided that adjoining bodies have at least one point in common and that no closed loops are formed.) In fact, except for the fluid force modeling, the fundamental algorithms of UCIN-CABLE are the same as for the previously developed program UCIN-SUPER [7]. The dynamical formulations and fundamental

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* Numbers in brackets refer to References at the end of the Report.

algorithms in that program are based on Lagrange's form of d'Alembert's principle or Kane's equations [8-11] and other vector-tensor-matrix methods. The fluid effects were simply "added" to this formulation to form UCIN-CABLE. A detailed description of the dynamical principles and methods and the fluid force model appears in references [1-6].

The attractive features of UCIN-CABLE's cable model are as follows: 1) the arbitrary dimensions and physical parameters of the segments; 2) the arbitrary specification of externally applied forces; 3) the use of relative orientation angles between the links to define the system configuration; and 4) the use of Lagrange's form of d'Alembert's principle to develop the governing equations of motion. Lagrange's form of d'Alembert's principle has been shown, for large systems, to possess the advantages of both Lagrange's equations and Newton's law, but without the corresponding disadvantages. That is, the principle provides for automatic elimination of unknown "non-working" internal constraint forces without introducing tedious differentiation of scalar energy functions. Finally, the governing dynamical equations are integrated numerically using a fourth order Runge-Kutta method.

The user's manual is divided into four sections with the first describing the scope and range of applicability of the program. The second section describes the physical data and governing variables of the finite segment model, and the data for the surrounding water, needed to run the program. The third section provides detailed (card image) instructions for the input data and the fourth section describes the output data.

II. SCOPE AND RANGE OF APPLICATION

The program is designed to numerically perform the following dynamical analyses:

1. Given the physical data (sizes, masses, inertias, and assemblage) of each body in the system, given the forces applied to reference point of body 1, given the external forces and torques applied to each of the bodies, and given information about the surrounding fluid (ambient velocity, density, viscosity, surface height, etc.) the kinematics (position, velocity, acceleration, angular velocity, and angular acceleration) of each body is determined. (Since the cable is assumed perfectly flexible, the connecting ball and socket joints are free, and hence the torques between adjoining bodies are zero.)

2. Given the physical data, given the kinematics of the reference point of body 1, given the external forces and torques applied to each of the bodies, and given information about the surrounding fluid, the required driving forces for the reference point of body 1 and the kinematics of each body is determined.

III. PHYSICAL AND FLUID DATA AND GOVERNING VARIABLES

This section describes the physical data characterizing the finite segment model and the data for the surrounding fluid, needed as input for the program. The variables (coordinates) defining the kinematics are also discussed and defined.

1. Chain Assemblage - Body Connection Array.

Consider again the chain system shown in Figure 1. Let the 8 bodies of the chain be labeled B_i (i=1,...,8) with B_1, the reference body, being chosen as the segment at the beginning of the cable. The other bodies are labeled outward along the "branches" and clockwise as shown in Figure 2. This assemblage is entered into the program through an array called JFV_i which lists for each B_i (i=1,...,N) (for N bodies) the adjacent lower numbered body. For example, for the chain system in Figure 2., the JFV array is:

$$JFV = (0, 1, 2, 3, 4, 2, 6, 7)$$

where 0 (zero) refers to an inertial reference frame R.

2. Masses.

The mass of each body must be known for input data. The usual units are slugs or kilograms although any system of units may be used.

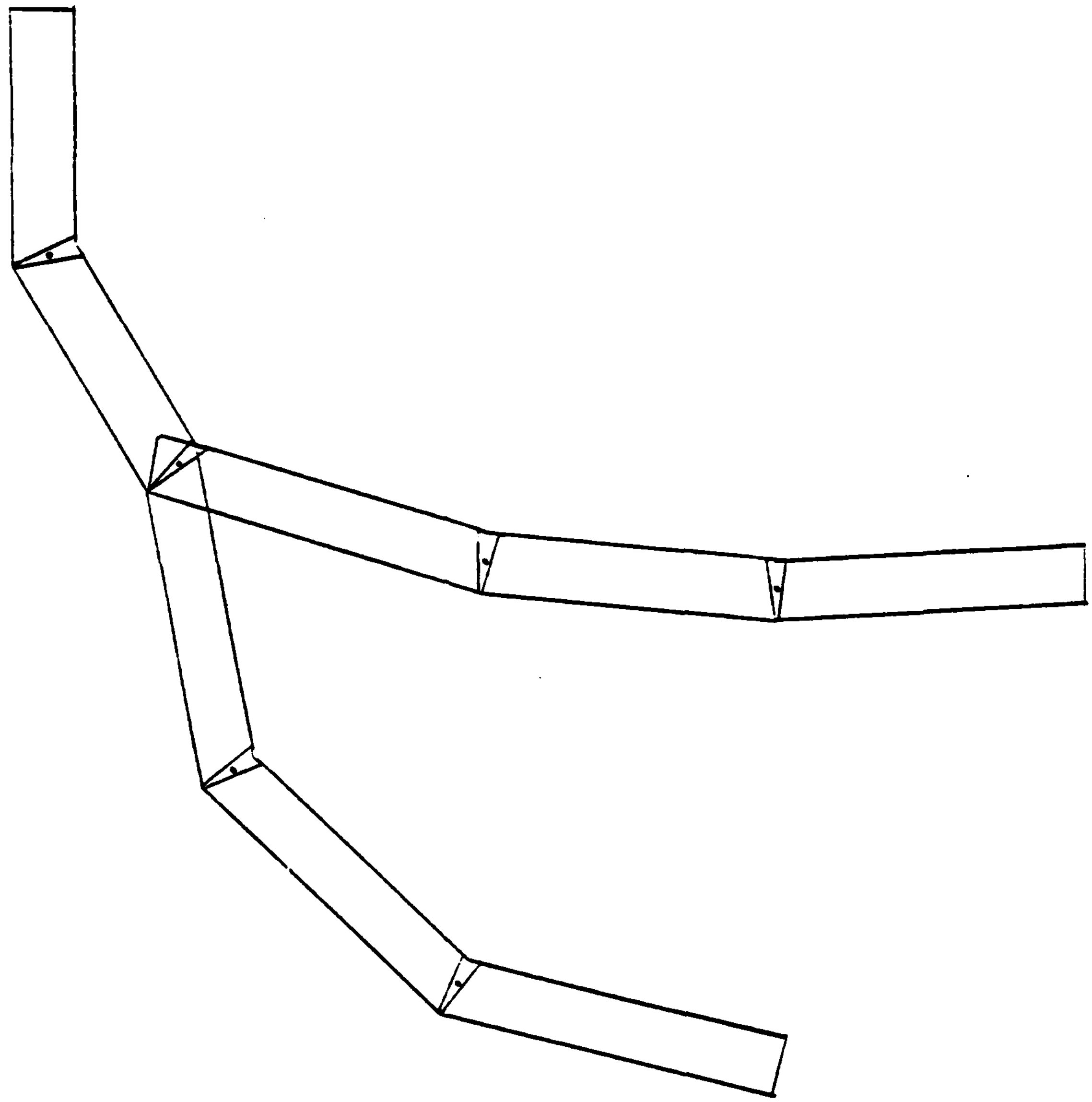


Figure 1. A Finite Segment Cable Model.

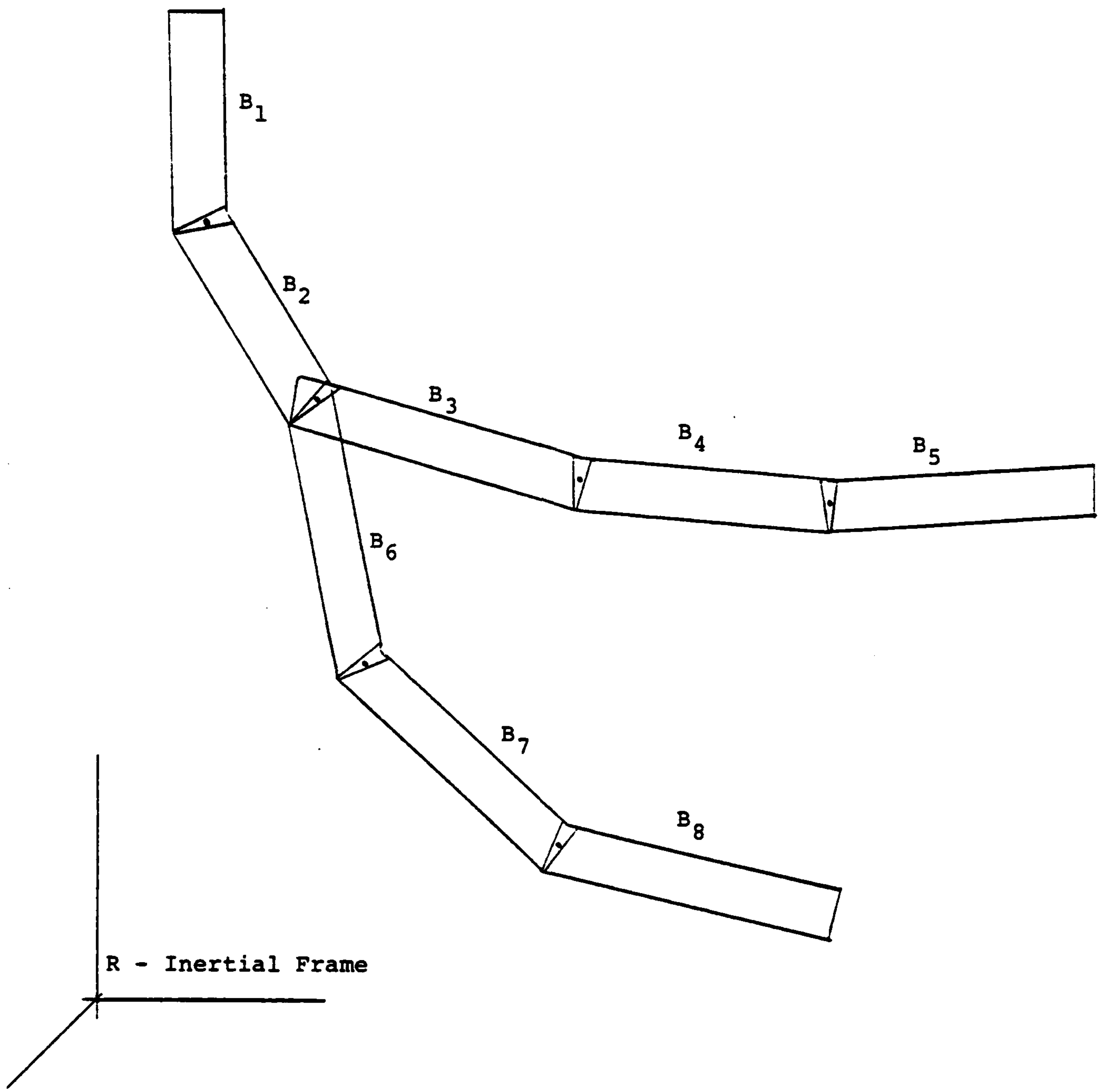


Figure 2. Numbering of the Segments.

3. Inertia Matrices.

The inertia matrix (moments and products of inertia) for each body referred to mutually perpendicular body fixed, coordinate axes passing through the mass center G_i, must be known for each body B_i ($i=1,\ldots,N$). The usual units are slug-in^2, slug-ft^2, or kg-m^2.

4. Mass Center Locations -- R-Vectors.

Let O_1 be an arbitrarily chosen reference point of B_1. Let O_i be a reference point of B_i ($i=1,\ldots,N$) and let O_i be the common point of B_i and its adjacent lower numbered body. (See Figure 3., for example.) Let G_i be the mass center of B_i. Then the vector $\underset{\sim}{r}_i$ from O_i to G_i locates the mass center. $\underset{\sim}{r}_i$ is fixed in B_i and its components (required as input) are referred to the body-fixed coordinate axes of B_i.

5. Reference Point Locations -- ξ-Vectors.

Let $\underset{\sim}{\xi}_i$ be the vector from the reference point of the adjacent lower numbered body of B_i to the reference point of B_i. Then $\underset{\sim}{\xi}_i$ is fixed in the adjacent lower numbered body and its components (required as input) are referred to the body-fixed coordinate axes of the adjacent lower numbered body of B_i. (See Figure 3.)

6. Variable Definition.

If the chain system contains N bodies, 3N+3 variables (coordinates) are required to define the position and

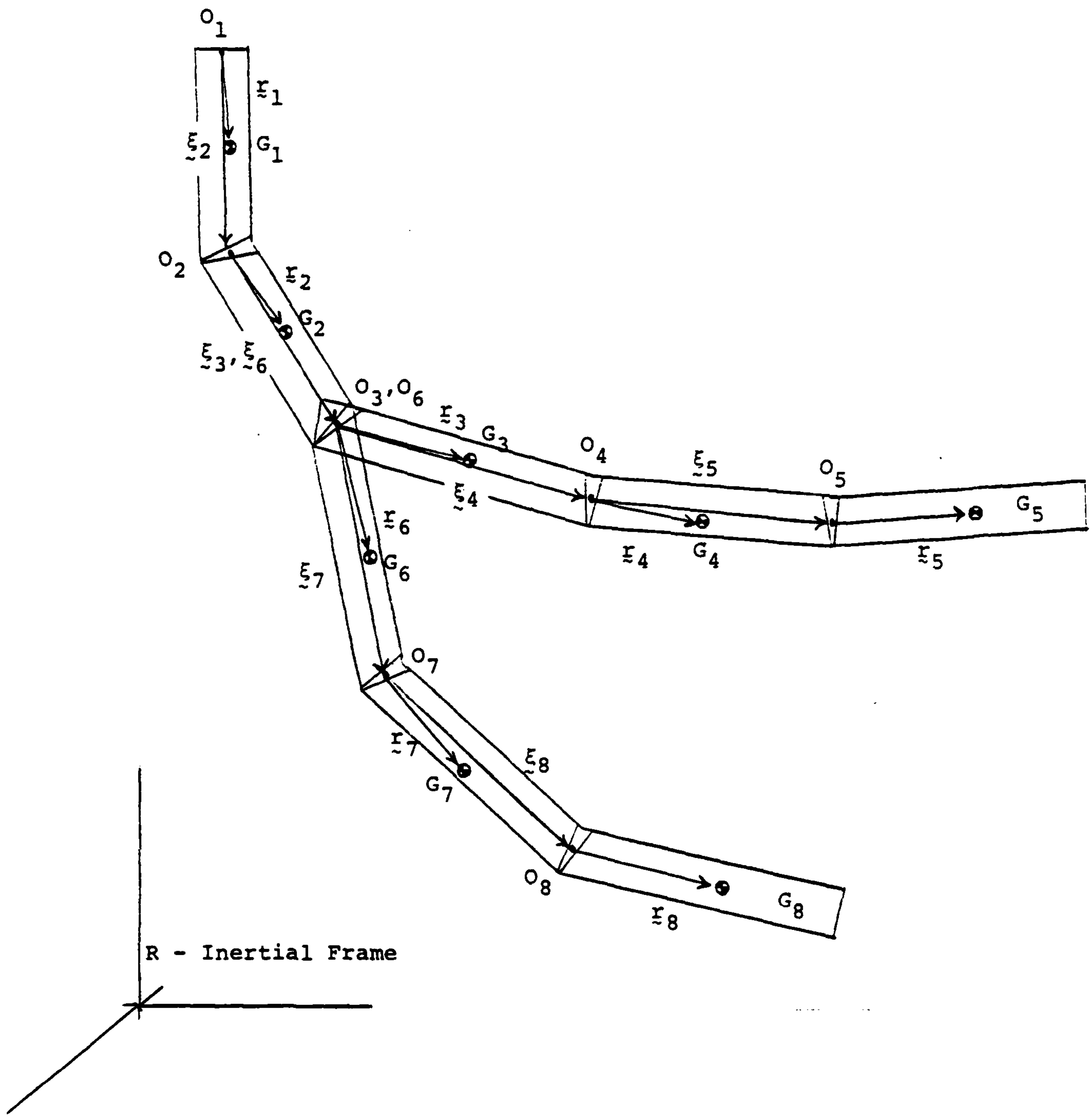


Figure 3. Mass Center and Joint Position Vectors.

configuration of the system. This can be seen by observing that three variables are needed to locate O_1 relative to the inertial frame R; three are needed to define the orientation of B_1 in R; and three are needed to define the orientation of each of the remaining N-1 bodies relative to their adjacent, lower numbered bodies.

Let these 3N+3 variables be called X_j (j=1,...,3N+3) and consider them in succession in sets of three each. Then each set except the first may be considered as three orientation angles α_i, β_i and γ_i of B_i relative to its adjacent, lower numbered body. These orientation angles are discussed in detail in the Appendix, but they are basically angles obtained by three successive dextral rotations of B_i relative to its adjacent, lower numbered body about its body-fixed coordinate axes.

7. Specified Motion of the Bodies of the System.

If the motion of some of the bodies of the chain system is known, the corresponding variables (coordinates) may be specified through functions of time, etc. in SUBROUTINE START of the program.

In many cases (e.g., finite segment model of a towed cable), it is desired to specify the acceleration of some of the bodies. Sometimes the desired acceleration is known simply in terms of a curve or data points rather than through elementary functions. To

accomodate this situation, the program will "read in" the second derivative of the variables at selected time intervals. The program has the capability of including 25 points of an acceleration curve.

To be more specific, consider the acceleration curve and the straight line approximation shown in Figure 4. The acceleration, velocity, and displacement during the i^{th} time interval are then:

$$a = a_i + \left(\frac{a_{i+1} - a_i}{t_{i+1} - t_i} \right) (t - t_i)$$

$$v = v_i + a_i(t - t_i) + \left(\frac{a_{i+1} - a_i}{t_{i+1} - t_i} \right) \frac{(t - t_i)^2}{2}$$

$$d = d_i + v_i(t - t_i) + a_i \frac{(t - t_i)^2}{2} + \left(\frac{a_{i+1} - a_i}{t_{i+1} - t_i} \right) \frac{(t - t_i)^3}{6}$$

where a_i, v_i, and t_i are the acceleration, velocity, displacement, and time at the beginning of the i^{th} interval. The motion of O_1 the reference point of B_1 is thus determined when the a_i are specified and when, v_1 and d_1, the initial velocity and displacement are given.

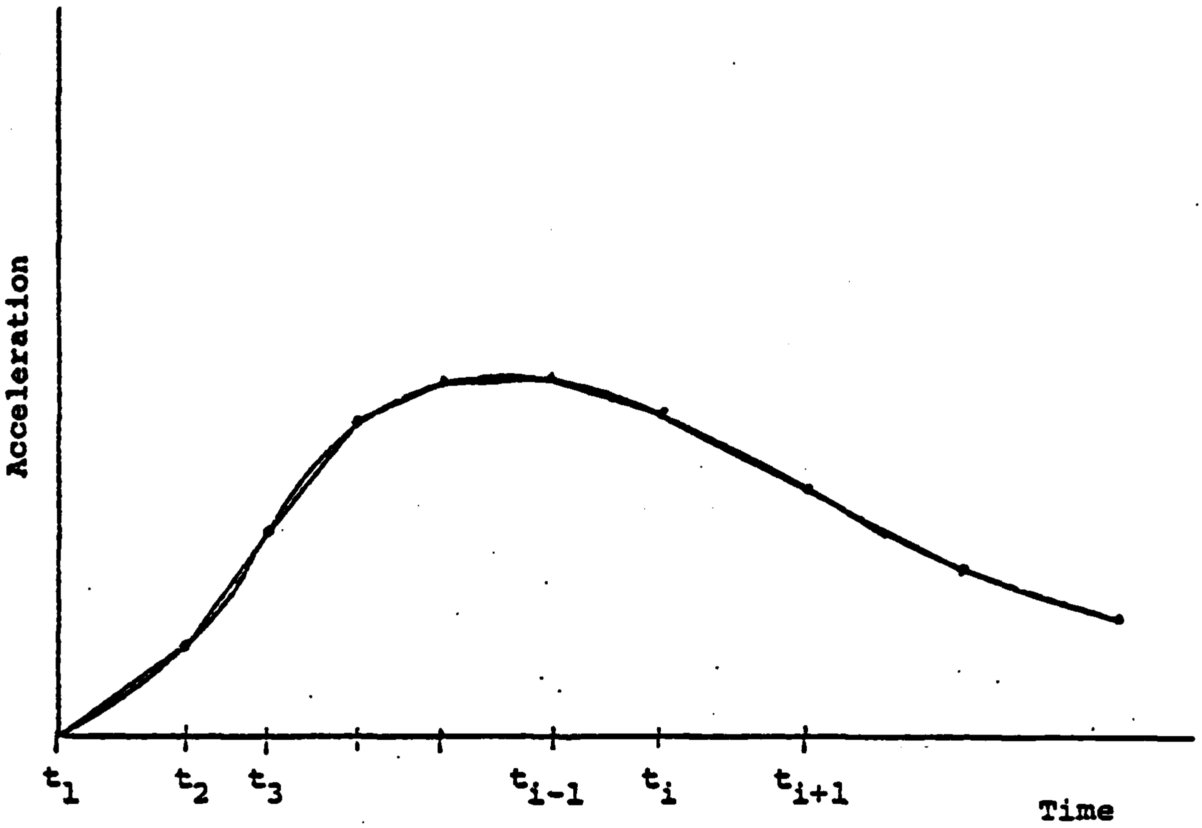


Figure 4. Acceleration Profile Approximation.

IV. INPUT DATA

The following paragraphs describe the card image requirements for the input data. An example listing is provided in the next section.

1. START OF DATA Card. The first card must read "*START OF DATA*". (See example input.)

2. Number of Bodies. The next card contains the number of bodies in the chain system NB, read in I5 format.

3. Mass Center Labels. The program provides an option of labeling or naming the mass centers of the bodies of the system. Hence, the next card contains the number of mass center labels (names) to be assigned, read in I5 format. If no labels are to be read, a blank card is used.

   If the number read is ≥ 1, the next series of cards then contain the mass center labels (or names) (5 per card) read in 5A16 format until the total number read in 3 is exhausted.

4. Joint Labels. The program also provides an option of labeling or naming the connecting joints between the bodies. Hence, the next card contains the number of joint labels (or names) to be assigned, read in I5 format. If no labels are to be read, a blank card is used.

If the number read $\geq$ 1, the next series of cards then contain the joint labels (or names) (5 per card) read in 5A16 format until the total number read in 5. is exhausted.

5. Output Printing Reference Body. Let the bodies of the chain system be numbered as discussed in the previous section. Then the next card contains the body number or that body which is to be an "output printing" reference body of the system, read in I5 format. (Usually this will be body 1 but it can be any body of the system.)

6. Body Connection Array. Next, the body connection array JFV(I) (See the previous section for a description.) is read with 10 numbers per card in 10I5 format.

7. Acceleration of Gravity. The next card contains the acceleration of gravity to be used by the program, read in F10.9 format. The choice of this value sets the units of length and time. All other input data must correspond to these units. (Since the dynamics formulation is independent of units, the output will reflect these units as well.)

8. Body Types for Masses and Inertia Matrices. The next series of cards is used to read or input the masses and

inertia matrices for the bodies of the system. In many cases, a number of the bodies of the chain system are identical. Hence, the first card in this series contains a number KT read in I5 format specifying the number of different types of bodies. (If KT=0, the bodies are considered to be all distinct for the purposes of input data, even though some may be physically the same.)

9. <u>Masses</u>. If KT=1, all bodies are considered identical, each having the same mass. In this case, the next card contains one number read in F10.9 format signifying that mass.

   If KT≠1, all bodies are considered to have different masses (even though some may be the same). Hence, in this case, the masses for the NB bodies are read sequentially in the next series of cards in 5F10.9 format.

   Together with the acceleration of gravity (L/T^2) the masses (M) complete the choice of units for the program. All input data to follow must be consistent with this choice. Note also that the output of the program will reflect the units of the input data.

10. <u>Inertia Matrices</u>. If KT≠0, that is, if there are several (at least 1) types of identical bodies, then the next card contains the number of bodies of the first type

followed (on the same card) by the body numbers for the bodies of the first type, read in 10I5 format. This card is immediately followed by three cards, three values per card in 3F10.9 format specifying the inertia matrix for the first type. This procedure is then repeated for the next type and continued until all KT types are exhausted.

If KT=0, the inertia matrices for the NB bodies of the system are considered to be distinct (even though some may be the same). In this case, the inertia matrices for the NB bodies are read in sequence with three values per card in 3F10.9 format.

11. Mass Center Positions: $\underset{\sim}{r}$ Vectors. The next series of cards is used to read or input the mass center positions for the bodies of the system -- the $\underset{\sim}{r}$ vectors (See previous section). The first card in this series contains a number K specifying the number of different kinds or types of identical bodies, with respect to mass center location, read in I5 format.

If K>0, that is, if there are several (at least 1) types of identical bodies, then the next card contains the number of bodies of the first type followed (on the same card) by the body numbers for the bodies of the first type, read in 10I5 format. This card is immediately followed by a card specifying the values of the three

components of the r vector, three values per card in 3F10.9 format. This procedure is then repeated for the next type and continued until all K types are exhausted.

If K=0, the mass center positions for the NB bodies of the system are all considered to be distinct (even though some may be the same). In this case, the $\underset{\sim}{r}$ vectors are read in sequence with three values (the components) per card in 3F10.9 format.

12. <u>Joint Positions: $\underset{\sim}{\xi}$ Vectors</u>. Similarly, the next series of cards is used to read or input the joint (or reference point) positions for the bodies of the system (except, of course, B_1). These are the NB-1 $\underset{\sim}{\xi}$ vectors. (See previous section.) The first card in this series contains a number K specifying the number of different kinds or types of identical bodies, that is, bodies with identical $\underset{\sim}{\xi}$ vectors, read in I5 format.

If K>0, that is, if there are several (at least 1) types of identical bodies, then the next card contains the number of bodies of the first type followed (on the same card) by the body numbers for the bodies of the first type, read in 10I5 format. This card is immediately followed by a card specifying the values of the three components of the $\underset{\sim}{\xi}$ vector, three values per card in 3F10.9 format. This process is then repeated for the next type and continued until all K types are exhausted.

If K=0, the joint positions are all considered to be distinct (even though some may be the same). In this case the NB-1 $\underset{\sim}{\xi}$ vectors are read in sequence with three values (the components) per card in 3F10.9 format.

13. Magnetic Tape Card. A zero or blank card should be read here if no magnetic tape is to be used to record the output data. If a magnetic tape is to be used, a value K is read in I5 format indicating the output unit number.

14. Heading Card. On this card anything may be written as a heading for the particular data used. This heading appears at the beginning of each output data page.

15. Specified Motion for the Bodies of the System. (See previous section.) For the acceleration profiles described in the previous section, the data cards are coded as follows: The first card contains the number of profiles (up to 10) that are used, read in I5 format.

    The next cards contain the number of points (up to 25) and the variable numbers of the respective acceleration profile curve for each acceleration profile used. They are read sequentially in 10I5 format.

    The next group of cards contain the time and acceleration ordinate for each point of the respective profile curves which are used. The first card of each subgroup (i.e. for

each profile used) also contains the initial velocity and displacement for that profile. The data on these cards are read in 5F10.9 format.

16. Blank Cards. Two blank cards are included here.

17. Gravity Forces. If the bodies of the chain system are in a vertical (x_2) gravity field, a weight force is automatically introduced through the mass center of each of the bodies by reading 1 on the next card in I5 format. If gravity forces are not to be included automatically, a blank card or zero is read.

18. Normal Fluid Drag. If the cable segments of the chain system are immersed in a fluid bath, a normal drag force is automatically introduced through the mass center of each of the segments and a normal drag torque is automatically applied to each of the segments by reading a 1 on the next card in I5 format. If normal drag forces and torques are not to be included automatically, a blank card or zero is read.

19. Tangential Fluid Drag. If the cable segments of the chain system are immersed in a fluid bath, a tangential drag force is automatically introduced through the mass center of each of the segments by reading a 1 on the next card in I5 format. If tangential drag forces are not to be included automatically, a blank card or zero is read.

20. Added Mass Effect. If the cable segments of the chain system are accelerating in a fluid bath, an added mass force is automatically introduced through the mass center of each of the segments and an added mass torque is automatically applied to each of the segments by reading a 1 on the next card in I5 format. If the added mass forces and torques are not to be included automatically, a blank card or a zero is read.

21. Buoyancy Force. Buoyance forces are automatically introduced through the mass center of each of the bodies (cable segments and spherical bodies) by reading a 1 on the next card in I5 format. If the buoyancy forces are not to be included automatically, a blank card or a zero is read.

22. Two Dimensional Motion. The next card contains a dimension specification switch, read in I5 format. If the value 1 is read, a two-dimensional dynamics analysis ensues. This cuts computer run time required for the problem solution, but is otherwise transparent to the user. Motion is assumed to take place in the Z-Y plane and the input data must correspond accordingly. If the value 0 (zero) is read, the standard three-dimensional analysis is performed.

23. Known and Unknown Variables. In most problems, some of the variables will be specified (known) and the remaining

variables are to be determined (unknown). To identify these variables, proceed as follows: Let KT be the number of known variables; or alternatively, let -KT be the number of unknown variables. Hence, on a card in I5 format read either KT (positive number representing the number of known variables) or -KT (negative number representing the number of unknown variables).

Next, in 10I5 format using as many cards as needed, read the variable numbers (e.g. 7 for X_7, etc.) for the KT known variables or the -KT unknown variables, according to whether KT or -KT is read in the previous card.

Finally, if KT=0 (i.e. a blank card), all variables are considered unknown.

24. Initial Values of the Variables. The initial values of the variables are included as input whether the variables are known (specified) or unknown (to be determined). If the variables are known and the initial values are different than the initial values of the specified function, say in SUBROUTING START, then the latter will be given preference in the program.

It is convenient to consider the variables and hence, their initial values in groups of three, with the first group being the displacement of B_1 in reference frame R. This group is designated as the "R-group" or "body-zero" group.

The ordering of the variables within the group is the natural or usual order: $x_1=x$, $x_2=y$, and $x_3=z$. The next group of three variables are the orientation angles of Body 1 and they are designated as the B_1 group. The ordering of the variables within the group is again the natural or usual order with $x_4=\alpha_1$, $x_5=\beta_1$, and $x_6=\gamma_1$. This procedure is continued through the 3NB+3 variables and the NB bodies, so that in general the group of variables associated with body B; (the "B_j" group) are the three variables defining the orientation of B_j relative to its adjacent lower-numbered body, with the usual ordering: α,β,γ.

There are several options available for the input of the initial values of these variables: i) They may be read in sequence; ii) They may be read at random (in groups of three); or iii) They may be read in groups of three -- when identical values are involved.

To actuate one of these options, read a number K in I5 format on a card, with the input data following on subsequent cards according to the following direction:

If K=0 (or a blank card), the initial values are read sequentially in groups of three with three values per card in 3F10.9 format (from "body-zero" to "body-NB" (NB+1 cards)).

If K<0, the initial values of the variables are read in -K groups of three, but the groups themselves may occur in random order. Also, if fewer than the NB+1 groups are read, the initial values of the variables associated with the groups not read are automatically set equal to zero. To identify the groups, the first value on each card is the "body number" of the group in I5 format. The initial values of the variables are then read in F15.9, 2F10.9 format on the same card with a total of four values per card.

If K>0, the initial values of the variables are read in K groups of groups of three. (This option is used when the initial values of the variables between two or more groups, or bodies, are identical.) The cards are coded as follows: On the first card (following the card with K), read the number of groups (or bodies, with identical initial values of the variables) within the first group. Then read, on the same card, the corresponding body numbers. All numbers on this card are in 10I5 format. This card is immediately followed by a card specifying the three initial values of the variables in 3F10.9 format. This procedure is then repeated for the next group and continued until all K groups are exhausted.

The second option above is particularly helpful for making the initial values of all the variables zero. To do this, simply read K as -1 and follow this with a card having a value 1, read in I5 format.

25. Initial Value of the Derivatives of the Variables. These are read in exactly the same manner as the initial values of the variables as described in 24. above.

26. Printing Priority. On a single card in I5 format a number is read between -100 and +100 determining the amount of print-out for a given run as follows:

If 0, all print-out (the "standard print-out") for every printing time (see 27. below) is given.

If >10 printing of X and DX in radians is omitted.

If >20 printing of moments between bodies, FF and all fluid induced forces are omitted.

If >30 printing of DDX in degrees is omitted.

If >40 printing absolute and relative velocity and acceleration is omitted.

If >50 printing of mass center and joint position is omitted.

If >90 printing of X and DX in degrees is omitted.

If >95 All printing is omitted.

If >0 (negative) the corresponding print-out is given for all integration steps, and all print-out at every print time (see 27. below) is given. (For example, -100 gives the maximum possible print-out.)

27. Printing Time. This is a value read on a single card in F10.9 format determining the time increment for print-out. This may be the same or different (usually greater) than the integration time increment PRMT(3).

28. PRMT. This is an array of 4 numbers needed for the integration subrouting RKGS. They are entered on a single card in 5F10.9 format. The first number is the integration starting time, the second number is the integration ending time, the third number is the integration time interval, and the fourth number is the desired upper bound on the error of the integration.

If the third number PRMT(3) is read as zero, then PRMT(3) is automatically set to 0.1. If PRMT(3) is read as negative, say -M, then PRMT(3) is automatically set to 2^{-M}.

If PRMT(4) is read as zero, then PRMT(4) is automatically set to 0.001.

29. Fluid Data. The next three cards are used to read fluid related data. The first card contains the inertial components of the fluid velocity in a 5F10.9 format. The second card contains the inertial components of the fluid acceleration in a 5F10.9 format. (Note: Since the fluid velocity is currently assumed constant in space and time, the components of the fluid acceleration must be zero.) The third card contains values for the Y coordinate of the

surface height of the fluid, the density of the fluid, and the viscosity of the fluid in 5F10.9 format.

30. Blank Card. A blank card is included here.

31. Number of Towed Spheres and Spherical Anchors. The next card contains the number of spherical bodies NSPHRB, read in I5 format. Note: These bodies may only be at the end of a branch.

32. Body Numbers of Towed Spheres and Spherical Anchors. The following card(s) contain the body number(s) of the spherical bodies, read in 10I5 format. If NSPHRB the number of spherical bodies is zero these cards are omitted.

33. Body Data. The next NB cards contain body data for each of the bodies of the chain system. There is one card for each body in sequence from body 1 to body NB. If the body is a cable segment then its data card contains its length, its diameter, and the segment fixed components of a unit vector parallel to the centerline of the segment, read in 5F10.9 format. (Note: The cable segments are assumed to be cylindrical in shape.) If the body is a spherical body, then its data card contains its diameter, read in 5F10.9 format.

34. END OF DATA Card. The last card must read "*END OF DATA*". (See example input data.)

V. EXAMPLE LISTING OF INPUT DATA

Figure 4. contains an illustration of a cable model. An example listing of the input data for this particular model is contained in the following pages.

CARD NO.	CONTENTS OF CARD	
1	*START OF DATA*	
2	13 NUMBER OF BODIES	
3	13 NUMBER OF CENTER OF MASS LABELS	
4	*C.M. BODY 1 **C.M. BODY 2 **C.M. BODY 3 **C.M. BODY 4 **C.M. BODY 5 *	MASS-CENTER LABELS
5	*C.M. BODY 6 **C.M. BODY 7 **C.M. BODY 8 **C.M. BODY 9 **C.M. BODY 10 *	
6	*C.M. BODY 11 **C.M. BODY 12 **C.M. OF ANCHOR*	
7	13 NUMBER OF JOINT LABELS	
8	*END OF BODY 1**END OF BODY 2 **END OF BODY 3**END OF BODY 4**END OF BODY 5*	JOINT LABELS
9	*END OF BODY 6**END OF BODY 7**END OF BODY 8**END OF BODY 8**END OF BODY 10*	
10	*END OF BODY 11**END OF BODY 12**END OF ANCHOR *	
11	1 REFFRENCE BODY	
12	0 1 2 3 4 5 6 7 8 9	BODY CONNECTION ARRAY
13	10 11 12	
14	386.4 ACC'N OF GRAVITY (SLUG, IN, SEC)	
15	0 ALL BODIES ARE DIFFERENT	
16	0.00011619 0.00014140.00012874 0.000142 0.0001372	MASSES
17	0.0001428 0.0001346 0.0001356 0.0001395 0.00013778	
18	0.0001379 0.000162310.00763975	
19	0.00024206 0.0 0.0	I(1)
20	0.0 0.0 0.0	
21	0.0 0.0 0.00024206	
22	0.0004363 0.0 0.0	I(2)
23	0.0 0.0 0.0	
24	0.0 0.0 0.0004363	
25	0.00032927 0.0 0.0	I(3)
26	0.0 0.0 0.0	
27	0.0 0.0 0.00032927	
28	0.0004419 0.0 0.0	I(4)
29	0.0 0.0 0.0	
30	0.0 0.0 0.0004419	
31	0.0003984 0.0 0.0	I(5)
32	0.0 0.0 0.0	
33	0.0 0.0 0.0003984	
34	0.0004491 0.0 0.0	I(6)
35	0.0 0.0 0.0	
36	0.0 0.0 0.0004491	
37	0.0003761 0.0 0.0	I(7)
38	0.0 0.0 0.0	
39	0.0 0.0 0.0003761	
40	0.0003845 0.0 0.0	I(8)
41	0.0 0.0 0.0	
42	0.0 0.0 0.0003845	

CARD NO.	CONTENTS OF CARD			
43	0.0004187	0.0	0.0	
44	0.0	0.0	0.0	I(9)
45	0.0	0.0	0.0004187	
46	0.0004036	0.0	0.0	
47	0.0	0.0	0.0	I(10)
48	0.0	0.0	0.0004036	
49	0.0004046	0.0	0.0	
50	0.0	0.0	0.0	I(11)
51	0.0	0.0	0.0004046	
52	0.0006600	0.0	0.0	
53	0.0	0.0	0.0	I(12)
54	0.0	0.0	0.0006600	
55	0.00381988	0.0	0.0	
56	0.0	0.00381988	0.0	I(13)
57	0.0	0.0	0.00381988	
58	0	ALL R VECTORS ARE DISTINCT		
59	0.0	-2.50	0.0	
60	0.0	-3.0425	0.0	
61	0.0	-2.77	0.0	
62	0.0	-3.0555	0.0	
63	0.0	-2.9515	0.0	
64	0.0	-3.072	0.0	
65	0.0	-2.8955	0.0	
66	0.0	-2.917	0.0	
67	0.0	-3.001	0.0	
68	0.0	-2.9645	0.0	
69	0.0	-2.967	0.0	
70	0.0	-3.4925	0.0	
71	0.0	-1.0	0.0	
72	0	ALL XI VECTORS ARE DISTINCT		
73	0.0	-5.0	0.0	
74	0.0	-6.085	0.0	
75	0.0	-5.54	0.0	
76	0.0	-6.111	0.0	
77	0.0	-5.903	0.0	
78	0.0	-6.144	0.0	
79	0.0	-5.791	0.0	
80	0.0	-5.834	0.0	
81	0.0	-6.002	0.0	
82	0.0	-5.929	0.0	
83	0.0	-5.934	0.0	
84	0.0	-6.985	0.0	

CARD NO.	CONTENTS OF CARD
85	0 MAGNETIC TAPE CARD
86	CABLE TEST 32: SIMULATED ANCHOR LAST DEPLOYMENT (SMALL SCALE) HEADING CARD
87	0 NUMBER OF ACCELERATION PROFILES
88	BLANK CARD
89	BLANK CARD
90	1 GRAVITY ON
91	1 NORMAL FLUID DRAG ON
92	1 TANGENTIAL FLUID DRAG ON
93	0 ADDED MASS EFFECT OFF
94	1 BUOYANCY FORCE ON
95	1 TWO DIMENSIONAL ANALYSIS (Z-Y PLANE) ON
96	-13 UNKNOWN VARIABLES
97	4 7 10 13 16 19 22 25 28 31 VARIABLE NUMBERS
98	34 37 40
99	0 INITIAL VALUES OF THE VARIABLES ARE ALL ARE DISTINCT
100	0.0 0.0 0.0
101	53.1301 0.0 0.0
102	8.40970 0.0 0.0
103	5.7368 0.0 0.0
104	0.81613 0.0 0.0
105	11.167 0.0 0.0
106	8.6868 0.0 0.0 INITIAL VALUES OF THE VARIABLES
107	6.9059 0.0 0.0
108	8.3023 0.0 0.0
109	4.7951 0.0 0.0
110	4.9799 0.0 0.0
111	5.6628 0.0 0.0
112	6.1415 0.0 0.0
113	0.0 0.0 0.0
114	-1 INITIAL VALUES OF THE DERIVATIVES OF THE VARIABLES IN 1 GROUP
115	1 0.0 0.0 0.0
116	11 PRINTING PRIORITY
117	0.0625 DELTA TIME FOR PRINTING
118	0.0 1.0 -6.0 0.001 0.0 PRNTR'S FOR RKCS
119	0.0 0.0 0.0 FLUID VELOCITY
120	0.0 0.0 0.0 FLUID ACCELERATION
121	12.0 0.0011491 .000002930 SURFACE HEIGHT, DENSITY, VISCOSITY
122	BLANK CARD
123	1 NUMBER OF SPHERICAL BODIES
124	13 SPHERICAL BODY NUMBER

CARD NO.	CONTENTS OF CARD					
125	5.0	0.163	0.0	-1.0	0.0	
126	6.085	0.163	0.0	-1.0	0.0	
127	5.54	0.163	0.0	-1.0	0.0	
128	6.111	0.163	0.0	-1.0	0.0	
129	5.903	0.163	0.0	-1.0	0.0	
130	6.144	0.163	0.0	-1.0	0.0	LENGTH, DIAMETER, UNIT VECTOR
131	5.791	0.163	0.0	-1.0	0.0	
132	5.834	0.163	0.0	-1.0	0.0	
133	6.002	0.163	0.0	-1.0	0.0	
134	5.929	0.163	0.0	-1.0	0.0	
135	5.934	0.163	0.0	-1.0	0.0	
136	6.985	0.163	0.0	-1.0	0.0	
137	2.0	DIAMETER OF THE SPHERE				
138	*END OF DATA*					

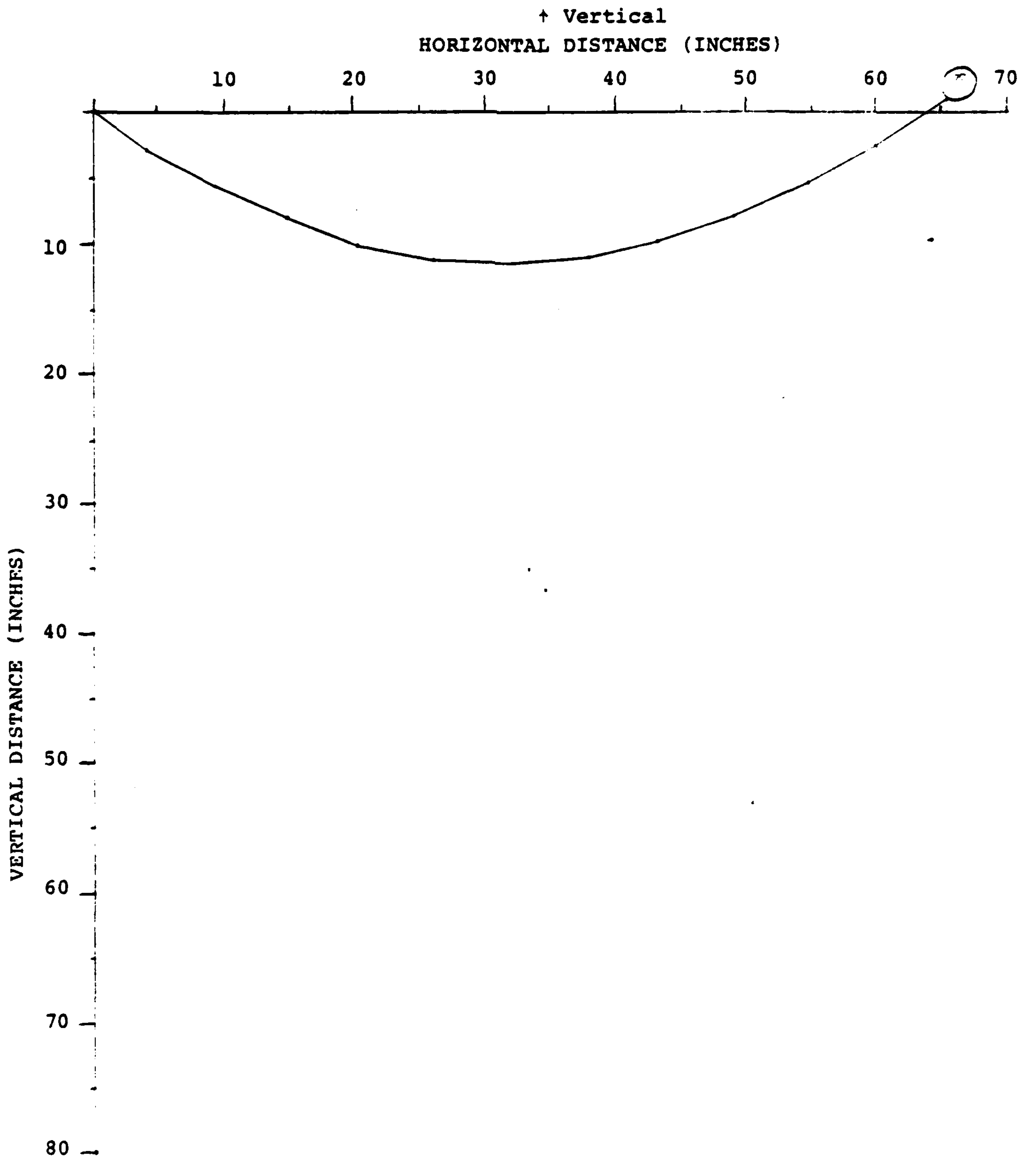


Figure 4. Plot of Initial Configuration for Example Listing of Input Data.

VI. OUTPUT DATA

The output data is labeled on the computer print-out and thus is primarily self-explanatory. It consists of two parts: The first part is simply an "echo" or copy of the input data. (In the input motion section, the velocity and position at the beginning of each acceleration interval is computed and also listed.) The second part contains at each output time (depending upon the printing priority (See 26, in the input section.)):

i) All variables and the first derivative of the variables (angles are in radians).

ii) Joint positions (in both inertia space and relative to the reference body).

iii) Mass center positions (in both inertia space and relative to the reference body).

iv) Mass center velocities and accelerations.

v) All variables and the first and second derivatives of the variables (angles are in degrees).

vi) Moments and forces associated with variables which are specified.

vii) Fluid induced forces and torques.

An example listing of output is contained in the following pages.

CABLE TEST 32: SIMULATED ANCHOR LAST DEPLOYMENT (SMALL SCALE)

TIME = 4500.000 MILLISEC

JOINT POSITION VECTORS

	IN INERTIA SPACE			RELATIVE		
END OF BODY 1	.0	-4.3198	-2.5179	.0	.0	.0
*END OF BODY 2 *	.0	-9.5812	-5.5748	.0	-6.0850	8.4496E-03
END OF BODY 3	.0	-14.361	-8.3407	.0	-11.625	3.6048E-02
END OF BODY 4	.0	-19.698	-11.353	.0	-17.735	.11068
END OF BODY 5	.0	-24.870	-14.199	.0	-23.637	.25669
END OF BODY 6	.0	-30.309	-17.057	.0	-29.775	.52644
END OF BODY 7	.0	-35.506	-19.610	.0	-35.581	.93771
END OF BODY 8	.0	-40.832	-21.993	.0	-41.352	1.5684
END OF BODY 8	.0	-46.415	-24.186	.0	-47.283	2.4791
END OF BODY 10	.0	-52.053	-26.032	.0	-53.080	3.7223
END OF BODY 11	.0	-57.803	-27.497	.0	-58.786	5.3518
END OF BODY 12	.0	-64.650	-28.665	.0	-65.324	7.8111
*END OF ANCHOR *	.0	-66.675	-28.905	.0	-67.160	8.6029

MASS CENTER POSITION VECTORS

	IN INERTIA SPACE			RELATIVE		
*C.M. BODY 1 *	.0	-2.1559	-1.2589	.0	.0	.0
*C.M. BODY 2 *	.0	-6.9505	-4.0463	.0	-5.5425	4.2248E-03
*C.M. BODY 3 *	.0	-11.981	-6.9577	.0	-11.355	2.2249E-02
*C.M. BODY 4 *	.0	-17.040	-9.8469	.0	-17.180	7.3421E-02
*C.M. BODY 5 *	.0	-22.284	-12.776	.0	-23.186	.18374
*C.M. BODY 6 *	.0	-27.589	-15.628	.0	-29.206	.39156
*C.M. BODY 7 *	.0	-32.908	-18.333	.0	-35.163	.73208
*C.M. BODY 8 *	.0	-38.169	-20.802	.0	-40.951	1.2491
*C.M. BODY 9 *	.0	-43.625	-23.090	.0	-46.817	2.0198
*C.M. BODY 10 *	.0	-49.236	-25.109	.0	-52.682	3.1007
*C.M. BODY 11 *	.0	-54.928	-26.764	.0	-58.433	4.5371
*C.M. BODY 12 *	.0	-61.247	-28.081	.0	-64.655	6.5815
C.M. OF ANCHOR	.0	-65.683	-28.785	.0	-68.742	8.2070

	MASS CENTER VELOCITIES			MASS CENTER ACCELERATIONS		
*C.M. BODY 1 *	.0	-.26983	.46294	.0	.16630	-5.7237E-02
*C.M. BODY 2 *	.0	-.86635	1.4881	.0	.51846	-.15772
*C.M. BODY 3 *	.0	-1.4864	2.5596	.0	.89037	-.27409
*C.M. BODY 4 *	.0	-2.0943	3.6237	.0	1.2675	-.41437
*C.M. BODY 5 *	.0	-2.6577	4.7040	.0	1.6110	-.50590
*C.M. BODY 6 *	.0	-3.2640	5.7569	.0	1.9456	-.62851
*C.M. BODY 7 *	.0	-3.7720	6.7543	.0	2.2323	-.72474
*C.M. BODY 8 *	.0	-4.1583	7.6608	.0	2.4539	-.79236
*C.M. BODY 9 *	.0	-4.5505	8.4569	.0	2.6425	-.87617
*C.M. BODY 10 *	.0	-4.8165	9.2299	.0	2.7709	-.93069
*C.M. BODY 11 *	.0	-4.9926	9.8259	.0	2.8686	-1.0306
*C.M. BODY 12 *	.0	-5.0949	10.297	.0	2.9273	-1.1197
C.M. OF ANCHOR	.0	-5.1368	10.560	.0	2.9266	-.97083

X ANGLE IN DEGREES

.0	.0	.0	30.236	.0	.0	-7.9556E-02	.0	.0
-.20567	.0	.0	-.41548	.0	.0	-.71534	.0	.0
-1.1000	.0	.0	-1.5563	.0	.0	-2.0547	.0	.0
-2.6774	.0	.0	-3.2968	.0	.0	-3.8352	.0	.0
-4.6756	.0	.0	-2.7101	.0	.0			

DX

.0	.0	.0	-12.281	.0	.0	3.4637E-02	.0	.0
8.9551E-02	.0	.0	.15740	.0	.0	.31861	.0	.0

.52515	.0	.0	.75730	.0	.0	.95949	.0	.0
1.2067	.0	.0	1.4072	.0	.0	1.5550	.0	.0
1.7591	.0	.0	.34729	.0	.0			

DDX

.0	.0	.0	1.0525	.0	.0	-.59006	.0	.0
.76942	.0	.0	-.37031	.0	.0	-1.0203	.0	.0
1.3614	.0	.0	-2.3269	.0	.0	1.3123	.0	.0
-1.4374	.0	.0	.33254	.0	.0	.22672	.0	.0
-.78467	.0	.0	-10.795	.0	.0			

FF

.0	1.4160	.82582	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0			

BUOYANCY FORCES

.0	1.1748E-02	-2.0155E-02	.0	1.4229E-02	-2.4490E-02	.0	1.2796E-02	-2.2204E-02
.0	1.3760E-02	-2.4285E-02	.0	1.2710E-02	-2.3100E-02	.0	1.2317E-02	-2.3440E-02
.0	1.0432E-02	-2.1235E-02	.0	9.0191E-03	-2.0154E-02	.0	7.4247E-03	-1.8915E-02
.0	5.3210E-03	-1.6248E-02	.0	3.3534E-03	-1.3158E-02	.0	1.8083E-03	-1.0666E-02
.0	1.8595	.0						

NORMAL DRAG FORCES

.0	1.5555E-04	-2.6688E-04	.0	1.4489E-03	-2.4938E-03	.0	3.4067E-03	-5.9122E-03
.0	6.8571E-03	-1.2102E-02	.0	1.0269E-02	-1.8663E-02	.0	1.4871E-02	-2.8301E-02
.0	1.8126E-02	-3.6895E-02	.0	2.1490E-02	-4.8020E-02	.0	2.3900E-02	-6.0885E-02
.0	2.3151E-02	-7.0691E-02	.0	2.0160E-02	-7.9102E-02	.0	1.6814E-02	-9.9176E-02
.0	6.5155E-02	-.13394						

TANGENTIAL DRAG FORCES

.0	.0	.0	.0	.0	.0	.0	1.1786E-07	6.7912E-08
.0	6.4872E-07	3.6756E-07	.0	2.1902E-06	1.2051E-06	.0	6.2365E-06	3.2770E-06
.0	1.3606E-05	6.6844E-06	.0	2.7719E-05	1.2405E-05	.0	6.2973E-05	2.0794E-05
.0	9.5075E-05	3.1136E-05	.0	1.9413E-04	4.9476E-05	.0	4.3599E-04	7.3917E-05
.0	.0	.0						

ADDED MASS FORCES

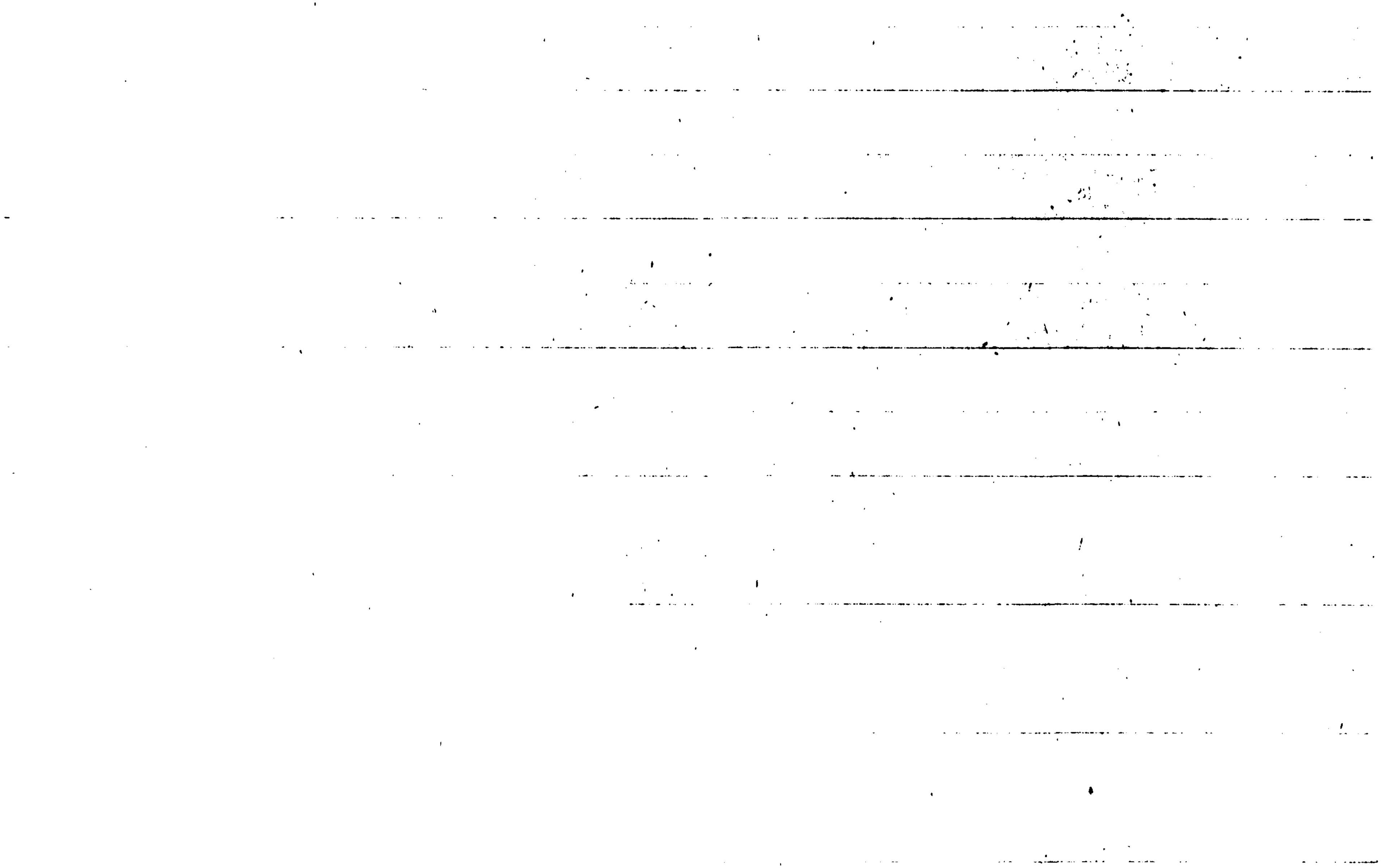
.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0						

NORMAL DRAG TORQUES

3.4618E-04	.0	.0	1.3132E-03	.0	.0	1.3752E-03	.0	.0
2.3223E-03	.0	.0	2.4460E-03	.0	.0	3.0826E-03	.0	.0
2.7793E-03	.0	.0	2.6882E-03	.0	.0	2.9986E-03	.0	.0
2.5552E-03	.0	.0	2.0585E-03	.0	.0	2.2729E-03	.0	.0
.0	.0	.0						

ADDED MASS TORQUES

.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0						



VII. COMMENTS ON UNITS AND ORIENTATION ANGLES

The units most frequently used in the program are: 1) slug-in-sec; 2) slug-ft-sec; and 3) kg-m-sec. However, any other set of consistent units may be used. The set of units the program uses is determined strictly by the input data. Whatever set is chosen by the user must be used for the input data, then the program will use this set as well.

There is a singularity present in orientation angles. The β rotation angle should not be allowed to go through 90°. This can usually be accomplished by properly defining the initial position of the model so that explicit motions relative to this initial position are such that β does not go through 90°.

APPENDIX

ORIENTATION ANGLES

As mentioned in the foregoing text, a majority of the dependent variables are angles measuring the relative orientation of adjacent bodies of the chain system. These angles are defined as follows: Consider two coincident dextral axes systems X_1, Y_1, Z_1 and X_2, Y_2, Z_2 as shown in Figure 6. Let X_1, Y_1, Z_1, be fixed in one of the adjacent bodies (the lower numbered body), and let X_2, Y_2, Z_2 be free to rotate relative to X_1, Y_1, Z_1 with the X_1 and X_2 axes remaining coincident. The angle α is then defined to be the dextral rotation of X_2, Y_2, Z_2 relative to X_1, Y_1, Z_1 as shown in Figure 7. Next, let X_3, Y_3, Z_3 be a third dextral axes system originally coincident with X_2, Y_2, Z_2. Let X_3, Y_3, Z_3 rotate relative to X_2, Y_2, Z_2 with Y_2 and Y_3 remaining coincident. The dextral rotation of X_3, Y_3, Z_3 about Y_2 and Y_3 defines the angle β as shown in Figure 8. Finally, let X_4, Y_4, Z_4 be a fourth dextral axis system originally coincident with X_3, Y_3, Z_3 and free to rotate relative to X_3, Y_3, Z_3 with the Z_3 and Z_4 axes remaining coincident. A dextral rotation about Z_3 and Z_4 defines the angle γ shown in Figure 9. Let X_4, Y_4, Z_4 be fixed in the other adjacent body (the higher numbered body). The three angles α, β, and γ thus measure the relative orientation of the two bodies.

In the foregoing text the variables are listed in groups of three. Those variables which are orientation angles are sequentially "α", "β" and "γ" angles as defined above.

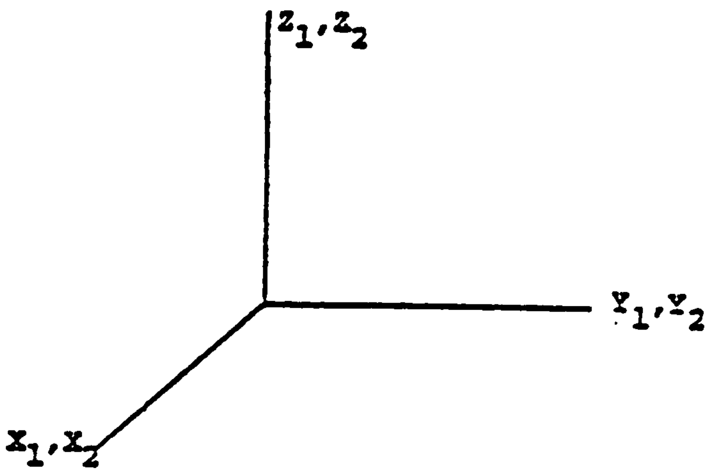


Figure 5.

Originally Coincident Axes.

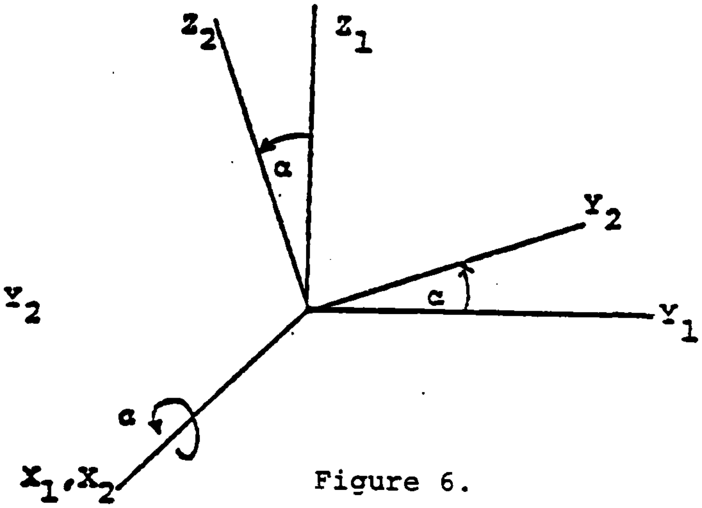


Figure 6.

α-Rotation.

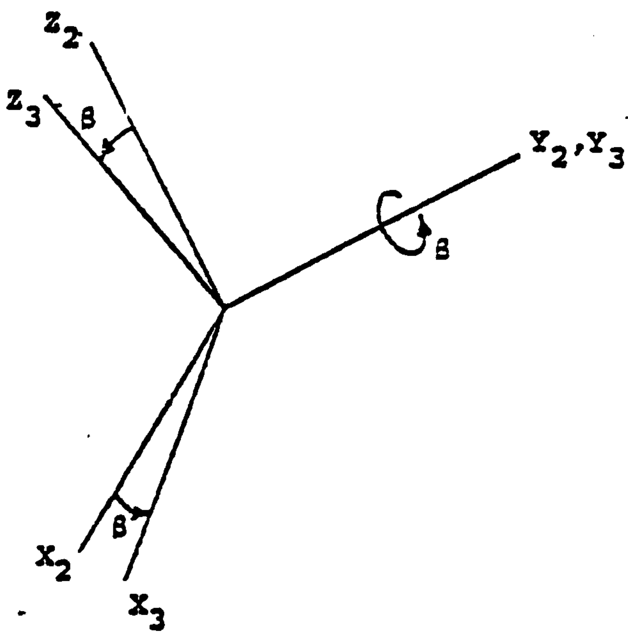


Figure 7.

β-Rotation.

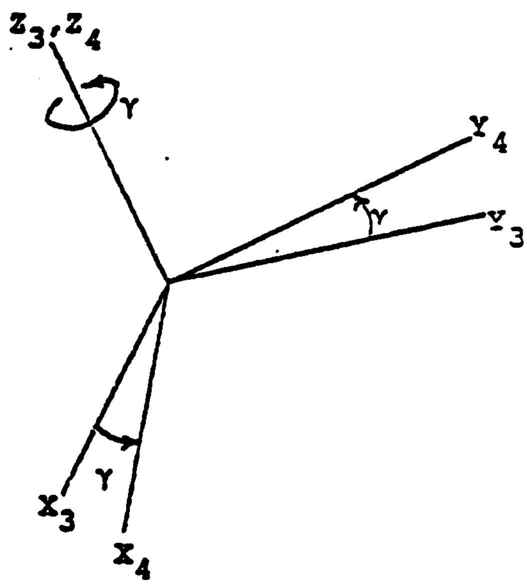


Figure 8.

γ-Rotation.

REFERENCES

1. R. L. Huston and J. M. Winget, "Cable Dynamics - A Finite Segment Approach," Computers and Structures, Vol. 6, 1976, pp. 475-480.

2. R. L. Huston and J. W. Kamman, "A Representation of Fluid Forces in Finite Segment Cable Models," Computers and Structures, Vol. 14, No. 3-4, 1981, pp. 281-287.

3. C. E. Passerello and R. L. Huston, "An Analysis of General Chain Systems," NASA-CR-127924, Report N72-30532, 1972.

4. C. E. Passerello and R. L. Huston, "Dynamics of General Chain Systems," NTIS Report PB257184, 1976.

5. R. L. Huston and C. E. Passerello, "On the Dynamics of General Chain Systems," ASME Paper No. 74-WA/Aut 11, 1974.

6. R. L. Huston and C. E. Passerello, "On Multi-Rigid-Body Systems Dynamics," Computers and Structures, Vol. 10, 1979, pp. 439-446.

7. R. L. Huston, C. E. Passerello, M. W. Harlow, and J. M. Winget," User's Manual for UCIN-SUPER: CHAIN SYSTEMS," NTIS Report PB247059, 1975.

8. T. R. Kane, "Dynamics of Nonholonomic Systems," Journal of Applied Mechanics, Vol. 28, 1961, pp. 574-578.

9. T. R. Kane, Dynamics, Holt, Rinehart and Winston, New York, 1968.

10. R. L. Huston and C. E. Passerello, "On Lagrange's form of d'Alembert's Principle," The Matrix and Tensor Quarterly, Vol. 23, No. 3, 1973, pp. 109-112.

11. T. R. Kane and D. A. Richardson, "Formulation of Equations of Motion for Complex Spacecraft," Journal of Guidance and Control, Vol. 3, No. 2, 1980, pp. 99-112.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents a computer program, UCIN-CABLE: Underwater Cables. The program is designed to study the dynamics of underwater cables. The cable is modeled as a series of rigid cylinders connected end-to-end by ball and socket joints. There may be one or many branches, and no closed loops are formed. The effects of normal fluid drag, tangential fluid drag, added mass, and buoyancy are included. This manual provides detailed instructions for building a set of input data and interpreting the output of the program.

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